The Carlyle Johnson Machine Company, LLC
General Clutch and Brake Selection Guidelines

1   Determining the size of a Clutch or Brake

To determine the appropriate size of a clutch or brake it is first necessary to determine what operational specifications are required. Those specifications include time, rotational speed, inertia load, the driving device, the driven elements, and the cycle rates. These operational specifications are evaluated through the use of a series of equations.

Frequently, the results of these equations will result in different clutch/brake selection values. For example, a clutch may be capable of providing adequate torque handling capacity for a system, but the cycle rate creates a heat load higher than that device can dissipate, in which case a larger clutch must be used in the application. In addition, there are external environmental variables which may influence the selection criteria. Is the device in an enclosed area where heat build-up could be a problem? Is the clutch or brake being run dry or in oil? What friction materials are available for the particular application being designed?

All of these variables must be carefully evaluated prior to final device selection. We recommend that you contact the factory for a review of your application prior to making a final selection. Our engineering expertise is always available to you for technical assistance.

1.1   Torque Based on the Drive and Driven Elements of a System

If you know the size of the driving device (such as an electric motor), the dynamic torque required can be calculated using the formula:

$$\text{Torque}_{ave} = \frac{(5250)\,(HP)\,(K_f)}{N_R}$$

Torque is expressed in (lb ft)
HP = Horsepower
(K_f) = Safety factor
N_R = Running speed (RPM)

Sample Calculation: Torque output of a 10 HP motor at 1,800 RPM with a clutch attached directly to the motor shaft:

HP = 10.0
(K_f) = 1.0 (for electric motors. Use 2.0 for internal combustion engines)
N_R = 1,800 RPM

$$\text{Torque}_{ave} = \frac{(5250)\,(HP)\,(K_f)}{N_R} = \frac{(5250)\,(10.0)\,(1.0)}{1800} = 29.17 \text{ lb ft}$$

Note that the above calculation does not address the type of driven element or the environment which the brake or clutch will see in operation.

The safety factor (K_f) used in the sample calculation is 1.0, suitable for a standard AC electric motor. However other oscillating or pulsed loads on the clutch output, or inherent torsional loading on the clutch input, would require a different factor.

1.2 Torque based on Inertia and Time

If you know the inertia load of the system, the speed at which the clutch or brake is operating, and the time allowed to accelerate the load from zero up to the full speed (or in the case of a brake to stop the load from full speed), then you can determine the torque required using the following formula:

$$\text{Dynamic Torque}_{ave} = \frac{(WR^2)\,(\Delta N)}{308(t)}$$

Dynamic Torque is expressed in (lb ft)
N = Speed (RPM)
$(\Delta N) = N_i - N_o$ where N_i = Input speed; N_o = Output speed
(WR^2) = Inertia (lb ft^2) of the clutch and system
$(WR^2) = (WR^2_{system}) + (WR^2_{clutch\ components})$
t = time (sec)

Sample Calculation: Torque required to accelerate an inertia load of 5 lb ft^2 from rest to 1,800 RPM in 0.5 seconds:

Start with a rough approximation of the dynamic torque, using the formula ((5 * 1,800) / (308 / .5)) = 58.44 lb ft. In the case of an electrically actuated clutch, the proper selection would be a model EMA0475, based on the table "Mechanical Data" found in Technical Bulletin 98, "Design Guidelines - Model EMA". For other methods of actuation, refer to the proper documentation on our web site. Verifying your model selection, complete the formula with the $(WR^2_{clutch\ components})$ found in the technical references mentioned:

(ΔN) = 1800 (accelerate from 0 to 1,800 RPM)
$(WR^2) = (WR^2_{system}) + (WR^2_{clutch\ components})$ = 5 lb ft^2 + .14 lb ft^2 (Model EMA0475) = 5.14 lb ft^2

$$\text{Dynamic Torque}_{ave} = \frac{(WK^2)\,(\Delta N)}{308(t)} \quad = \frac{(5.14)\,(1800)}{308(.5)} \quad = \frac{9252}{154} \quad = 60.08 \text{ lb ft}$$

In this example, the EMA0475 with a dynamic torque rating of 75 lb ft is indeed the appropriate selection for an electrically actuated clutch.

1.3 Thermal Requirements

The above examples must finally be tested against the heat load capacity of the selected device. Regardless of the torque requirements of the clutch or brake, the thermal capacity must be reviewed, to ensure that it does not overheat. The thermal loading of the clutch or brake is a direct result of the inertia, the speed, and the cycle (on/off) rate.

These will further be influenced by the type of actuation (electrical, mechanical, hydraulic, or pneumatic), the type of friction element used (steel, bronze, synthetic kevlar, etc.), and the physical size of the clutch or brake.

The thermal loading can be calculated using the formula below:

1.3 Thermal Requirements, continued

$$E = BTU/_{min} = \frac{1.7\,(WR^2)\,(RPM\,/\,100)^2\,(\text{Engagements per Minute})}{780}$$

$E = BTU/_{min} = $ Heat load
$(WR^2) = $ Inertia

Sample Calculation: Using the data from Section 2.1, determine the heat load with a cycle rate of 4 engagements per minute:

$$E = BTU/_{min} = \frac{1.7\,(WR^2)\,(RPM\,/\,100)^2\,(\text{Engagements per Minute})}{780} = \frac{1.7\,(5.14)\,(1800\,/\,100)^2\,(4)}{780}$$

$$= \frac{11324.45}{780} = 14.52\ BTU/_{min}$$

Again using the example of an EMA0475 electrically actuated clutch, the resulting heat dissipation rate of 13.5 BTU/minute is insufficient for this applicatioin. If an electrical EMA-type clutch is desired, the larger EMA0625 with a heat dissipation rate of 20.5 BTU/minute would be required for this application.

There are additional external considerations for thermal capacity of a clutch or brake. External environment, operating conditions, and method of actuation will all play a role. It is important that our engineering staff be consulted before final selection is made.
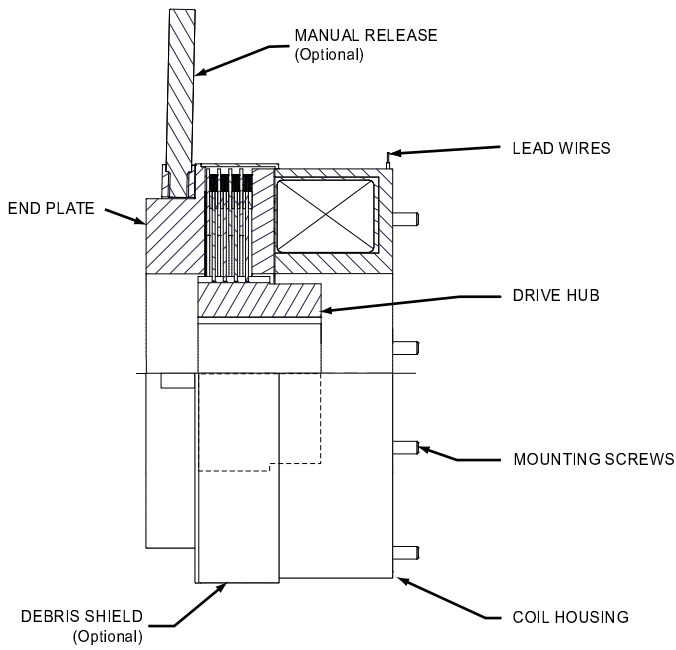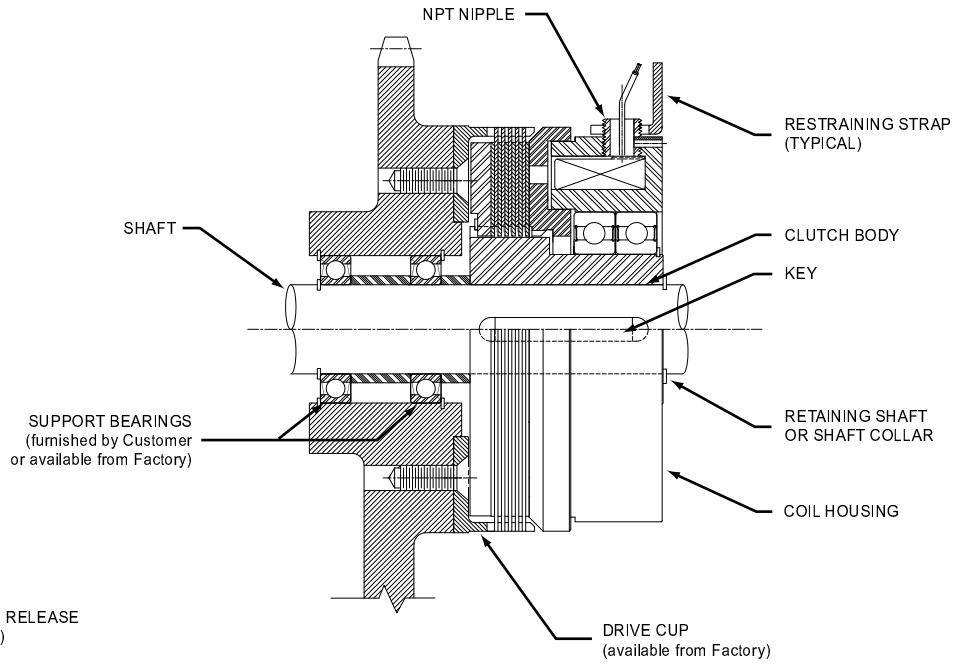
2   Alignment

The drive cup and the clutch or brake body must be held within .005 TIR when mounted. One design approach which will assure this concentricity is the use of an alignment bearing. The bearing and drive cup adapter are supplied by the customer or are available from Carlyle Johnson as an optional accessory; they are not included in the standard catalog clutch or brake configuration.

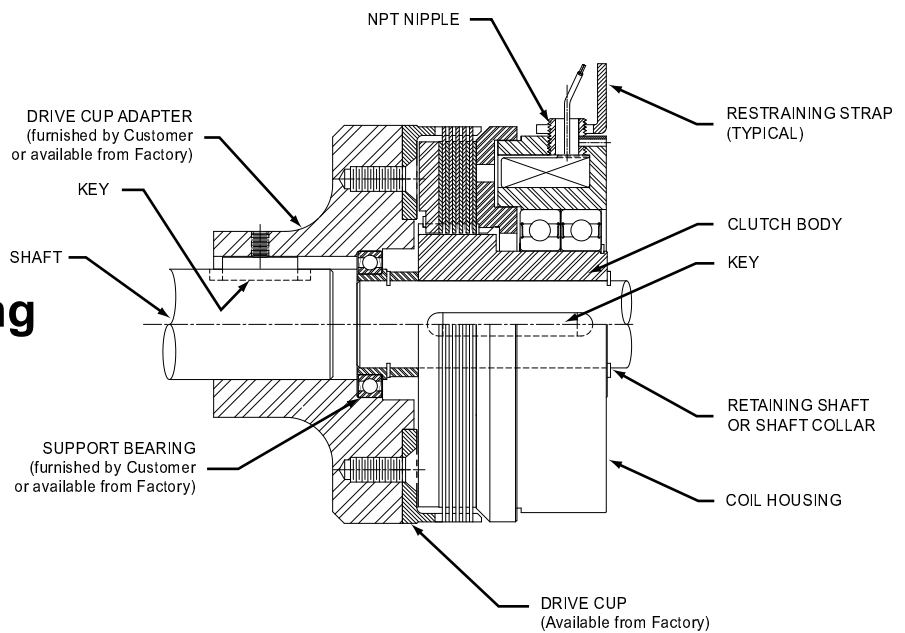Tolerances on axial position by model are shown in the application literature.

If an alignment bearing is not used, care must be taken during design to maintain both the cup-to-housing dimension, as well as their concentricity and angular displacement.

Clutch

NPT NIPPLE

RESTRAINING STRAP (TYPICAL)

SHAFT

CLUTCH BODY

KEY

SUPPORT BEARINGS (furnished by Customer or available from Factory)

RETAINING SHAFT OR SHAFT COLLAR

COIL HOUSING

DRIVE CUP (available from Factory)

Brake

MANUAL RELEASE (Optional)

LEAD WIRES

END PLATE

DRIVE HUB

MOUNTING SCREWS

DEBRIS SHIELD (Optional)

COIL HOUSING

Cut-off Coupling

NPT NIPPLE

RESTRAINING STRAP (TYPICAL)

DRIVE CUP ADAPTER (furnished by Customer or available from Factory)

KEY

CLUTCH BODY

SHAFT

KEY

SUPPORT BEARING (furnished by Customer or available from Factory)

RETAINING SHAFT OR SHAFT COLLAR

COIL HOUSING

DRIVE CUP (Available from Factory)

Formula 1
TORQUE CALCULATION FOR ELECTRIC MOTORS
(based on HP and RPM)

Torque (lb-in) based on HP and RPM: $T = \dfrac{HP \times 63025}{Motor\ RPM}$

Torque (lb-ft) based on HP and RPM: $T = \dfrac{HP \times 5250}{Motor\ RPM}$

Formula 2
HORSEPOWER OF ROTATING OBJECTS

$HP = \dfrac{Torque\ (lb\ ft)\ \times\ Shaft\ Speed\ (RPM)}{5250}$

Formula 3
HORSEPOWER OF OBJECTS IN LINEAR MOTION

$HP = \dfrac{Force\ (lb)\ \times\ Velocity\ (fpm)}{33000}$

Formula 4
INERTIA OF BARS, SHAFTS, or DISCS

Weight of bar/shaft/disc (in pounds): $wt = f \times r^2$ r = radius (inches)
                                                      f = factor (see below)

Radius of gyration for a cylinder: $R^2 = (1/2) \times (r/12)^2$ r = radius (inches)

Inertia per inch of length: $WR^2 = (wt) \times (R^2)$

Weight Factor per Inch of Various Materials (lbs)

Material		
Steel	f =	.890
Rubber	f =	.108
Nylon	f =	.161
Aluminum	f =	.310
Bronze	f =	1.010
Cast Iron	f =	.821

To Calculate the Inertia per inch of length for a Hollow Cylinder:

Subtract the WR^2 of the I.D. from the WR^2 of the O.D.

Reflected Inertia (Rotating devices)

Inertia calculations used to determine the proper size for a clutch or brake must take into account the ratio of the speed (in RPM) of the clutch and the speed (in RPM) of the other elements in the system. While horse-power is essentially unchanged throughout the system, inertia scales up or down proportionally in relation to

$$\text{Inertia at Clutch:} \qquad WR^2_{\text{at clutch}} \ = \ WR^2_{\text{at source}} \ \times \ \frac{RPM_{\text{at source}}}{RPM_{\text{at clutch}}}$$

Reflected Inertia (Linear devices)

Inertia calculations used to determine the proper size for a clutch or brake must take into account the load presented to the clutch from any linear devices being driven (such as a conveyor). This load can be reduced to an equivalent inertia value using the formula below. The critical information which must be determined is (1) the weight of the load; and (2) the diameter of the driving pulley, sprocket, gear, or drum.

$$\text{Inertia of Load:} \qquad WR^2_{\text{load}} \ = \ \text{Weight (lbs)}_{\text{load}} \ \times \ \left(\frac{DIA_{ft}}{2} \right)^2$$

Using the rotating device formula above, the inertia at the clutch can be calculated:

$$\text{Inertia at Clutch:} \qquad WR^2_{\text{at clutch}} \ = \ WR^2_{\text{load}} \ \times \ \frac{RPM_{\text{driving device}}}{RPM_{\text{at clutch}}}$$

DISCLAIMER